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Ecosystems and Oceans Science | Sciences des écosystèmes et des océans

Quebec Region

Canadian Science Advisory Secretariat
Science Advisory Report 2018/037

ASSESSMENT OF THE ESTUARY AND GULF OF ST. LAWRENCE (DIVISIONS 4RST) CAPELIN STOCK IN 2017

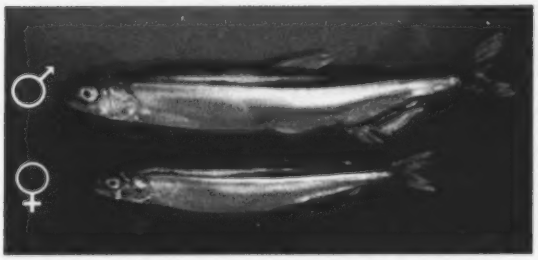

Figure 1. Adult male and female capelin (Source: Claude Nozères - DFO)

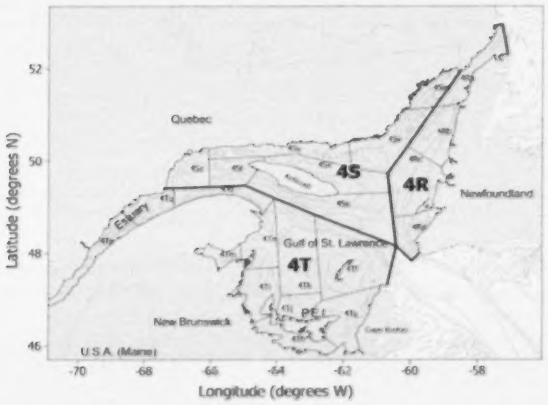

Figure 2. Map of NAFO Divisions 4RST (Estuary and the Gulf of St. Lawrence)

Context

Capelin (Figure 1) are small, schooling, forage fishes that play a central role in the St. Lawrence Gulf and Estuary ecosystems. Traditionally in Eastern Canada, capelin have been caught for consumption recreationally on beaches as they spawned and have also been used as fertilizer, bait, and for their oil. Towards the end of the 1970s, the emergence of an Asian market for roe-bearing females sparked a rapid growth of the fishery with mean catches increasing from approximately 662 t to nearly 10 000 t per year. In NAFO Divisions 4RST (Figure 2), most capelin catches are made on the West coast of Newfoundland by a fleet of small and large purse seiners, as well as by "tuck" seiners and traps. Capelin are also caught using traps on Quebec's Lower North Shore and weirs in the St. Lawrence Estuary. Capelin are a regular bycatch of commercial shrimp trawlers and of the multidisciplinary groundfish and shrimp surveys conducted annually by Fisheries and Oceans Canada in the Gulf and Estuary of St. Lawrence. Although the structure of capelin populations in the Estuary and Gulf of St. Lawrence is not clearly defined and recent genetic studies indicate that there are at least three capelin species in Canadian waters, capelin in 4RST are currently managed as a single stock.

A Total Allowable Catch (TAC) of 14 300 t is applied to all of the stock. This TAC is divided as follows: 12 314 t for 4R and 1 985 t for all of 4ST. The first directed abundance survey on Gulf capelin will occur in the spring of 2018. From this survey, it will be possible estimate capelin biomass and from this, help define a decisional framework for the fishery and a TAC based on the precautionary approach.

The last capelin stock assessment in 4RST was conducted in 2013 followed by an update in 2015. The goal of this document is to provide recommendations on the status of capelin in 4RST based on the best available data.

Canada

SUMMARY

- 2017 represented the lowest recorded landings (1 973 t) since 2001 (741 t) and a sharp drop from landings in 2016. The average capelin landings in NAFO Divisions 4RST from 2001 onwards has been 8 040 tonnes. The TAC is currently set at 14 300 t.
- Most of the landings are from a purse seine fishery on the West coast of Newfoundland (4R). The tuck seine fishery developed in the same region since 2005.
- Since 2013, fishing effort has moved northwards along the West coast of Newfoundland towards the Strait of Belle Isle, except for 2017 where the presence of ice and bad weather limited fishing activities.
- The 4R seiner fishery performance index has dropped considerably since 2013 but remains above the mean of the time series (1986-2017).
- Analyses suggest that capelin recruitment is associated with environmental factors such as temperature and the availability of zooplankton as prey.
- Since 2011, the condition of capelin caught in the commercial fishery has diminished and 2016 and 2017 are among the lowest recorded values in the time series.
- Since 2015, the measured sizes of capelin caught in the commercial fishery have diminished in most regions of the Gulf.
- Due to the decreasing fishery performance index, the decreasing biological indices, very low landings in 2017, and capelin's prominent role as a forage species in the ecosystem, a substantial decrease in the total allowable catch of capelin authorised for 2018 and 2019 is advised by virtue of precaution.

INTRODUCTION

Species Biology

Capelin were previously considered as a single circumpolar species, *Mallotus villosus*. However, increasing morphological and genetic evidence indicate that there are at least three capelin species inhabiting Canadian waters with complex genetic structures within each species (Mecklenburg et al. 2018, Mecklenburg and Steinke 2015). Genetic isolation among capelin species appears to coincide with lower ocean levels during the last major periods of glaciation. In Canada, Pacific capelin, *Mallotus catervarius* are observed from the Pacific Ocean through the Berring Strait, the Chukchi and Beaufort Seas, across the Artic, and as far East as the Davis Strait. Atlantic capelin consist of *Mallotus villosus* and a as of yet unnamed capelin species *Mallotus sp.* Atlantic capelin ranges overlap in the North Atlantic Ocean from Hudson's Bay to the Barents and Kara Seas and extend as far South as the Scotian Shelf and the Bay of Fundy in the North West Atlantic. All three capelin species' habitats overlap in Canadian waters and further studies are needed to define each of their habitat preferences, genetics, and life-history traits. In NAFO divisions 4RST, which cover the Estuary and Gulf of St. Lawrence, capelin are currently managed as a single stock with two distinct management units 4R and 4RST. However, due to the above mentioned genetic structure of capelin, they shall be referred to in the plural tense or as *Mallotus spp.* for the entirety of this document.

Capelin are members of the *Osmeridae* family (smelts) and range from a metallic blue, green, yellow-green, or brassy brown colour and have an elongated body shape. There is a clear sexual dimorphism among capelin where males have larger fins and are typically larger and

longer than females. In the spring and extending into the early summer, males also develop two pairs of spawning carina (prominent ridges), one dorsal and the other ventral (Figure 1).

Capelin have two modes of spawning (beach spawning and demersal spawning) and are preceded by large scale migrations to coastal and intertidal waters. Beach spawners "roll" onto sandy or fine gravel beaches where males and females deposit their respective milt and eggs (approximately 1 mm in diameter) which then adhere to the sandy substrate. Timing of beach spawning generally progresses from the West in the Estuary (April-June) eastwards and as late June-July along Quebec's Lower North Shore (Figure 3). These spawning events are thought to be more predominant at night at high tides. Onshore winds and lunar phase are also thought to influence spawning time and date. There is a high mortality among the mature fish, particularly the males, following beach spawning. Although many beaches are used year after year by capelin to spawn, water temperature is the likely driver of a beach being used for spawning or not. Capelin have been observed to spawn in waters ranging between 3-15 °C on beaches. Water and substrate temperatures also influence egg incubation time (0-35 days with faster incubation in warmer water), egg mortality, and larval survival but this varies across beaches and years. Similar to beach spawners, demersal spawners tend to choose sites with sandy or fine gravel substrate but are found in colder temperatures and higher salinities. Those who have observed demersal spawning sites describe swimming through thick clouds of eggs surrounded in a gelatinous substance that adheres to the seafloor. In addition to lower temperature variability at demersal spawning sites, demersal spawners experience higher salinities than beach spawners but the effect of salinity on incubation time, egg mortality, and larval survival is not clear. Upon hatching, larvae adopt a planktonic existence and remain near the water's surface until winter. The most significant amount of growth occurs in the first year and capelin reach sexual maturity around 2 years of age.

ANALYSIS

Commercial Fishery

Description of fishing activities

Capelin fishing seasons are generally short and coincide with the pre-spawning period for the seine fishery and to the spawning period for the trap and weir fisheries. Seiners and trap fisheries target mature females destined for export. This market was orginally a Japanese roe market but is now increasingly dominated by a small fish market for mostly female capelin in China. Males were historically discarded or used as feed but are now mostly sold to zoos and marine parks in the United States and in China. The emergence of these markets in the late 1970s was the cause for the sharp increase in landings which were observed (Figure 4). Catches tapered off from these high values to a low of 393 t in 1982 and then steadily increased until 1993. Landings dropped precipitously in 1994 and 1995 (966 t and 152 t respectively). Since 1996, total landings per year have averaged 7 786 t and have frequently exceeded 10 000 t. In 2017, the commercial fishery landings were 1 973 t, the lowest recorded value since 2001 (741 t). Most capelin landings in the Estuary and Gulf of St. Lawrence occur on the West coast of Newfoundland (4R) and are dominated by a purse seine fishery (Figure 5).

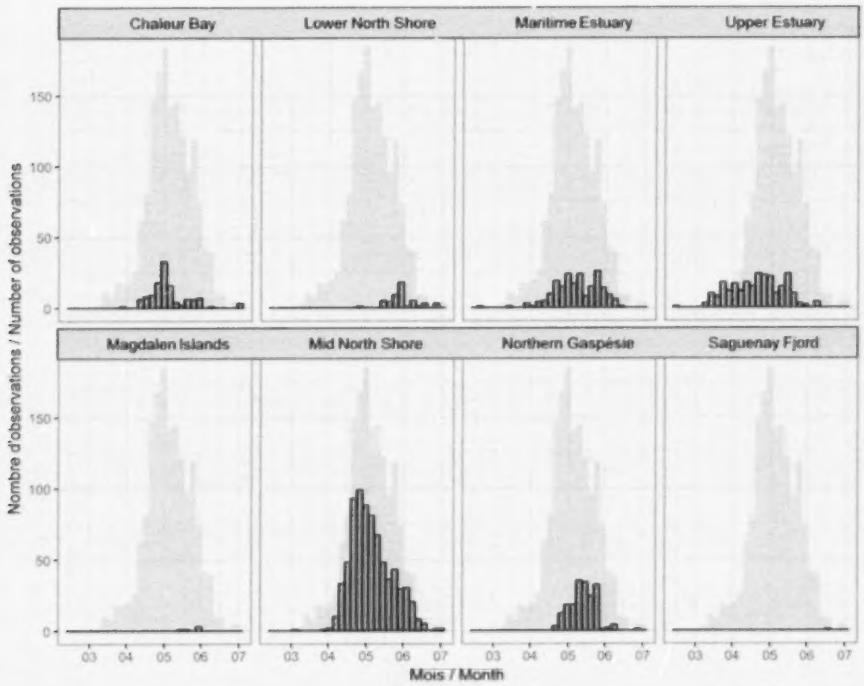

Figure 3. Capelin Beach spawning observations by Month (1945-2017) (Source: The St. Lawrence Global Observatory's Capelin Observers Network and Ecapelin). Each panel presents the sum of observations (in grey) accompanied by a histogram of each region's observations binned by week (in colour).

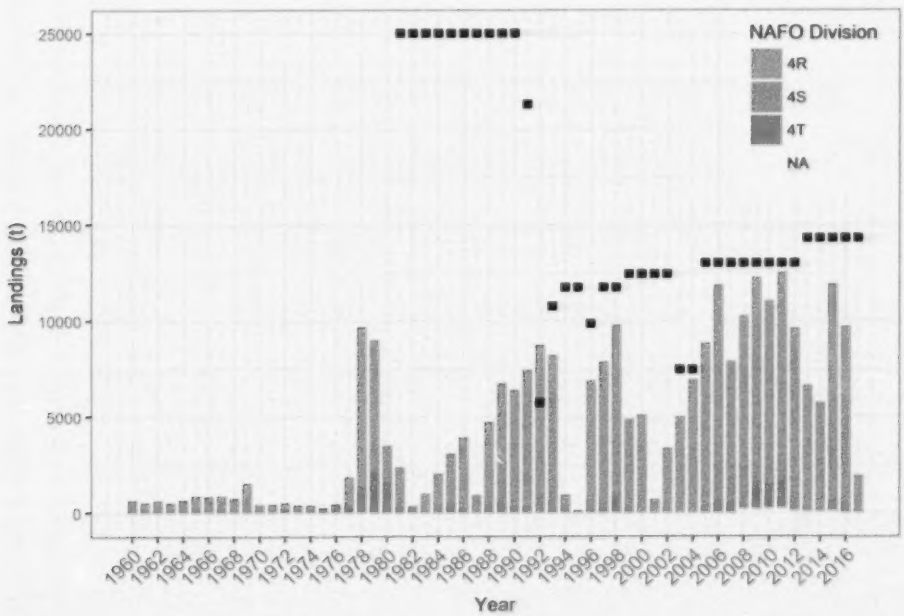

Figure 4. Capelin landings(t) and TAC (black squares) in NAFO Divisions 4RST from 1960 to 2017.

A TAC of 14 300 t was set for 4RST since 2013 and is split by fleet and NAFO Division. The 4R fixed gear fleet, which includes tuck seiners, is competitive but split between six sub-regions and has an allocation of 37.82% (5408.26 t) of the TAC. The 4R mobile gear fleet of vessels under 19.81 m (65 ft) is dominated by purse seiners and their allocation of 24.15% (3 453 t) of the TAC is managed through individual quotas (IQ). The 4R mobile gear fleet of vessels over 19.81 m (65 ft) is also composed predominantly of purse seiners and shares the same TAC allocation of 24.15% (3 453 t) as the smaller mobile gear fleet. The allocation for 4ST is 13.88% (1 985 t) of the total TAC and is managed as a competitive fishery across all gear types. NAFO Division 3Pn is included in the 4RST integrated fisheries management plan (IFMP) but has never been included in the stock assessment.

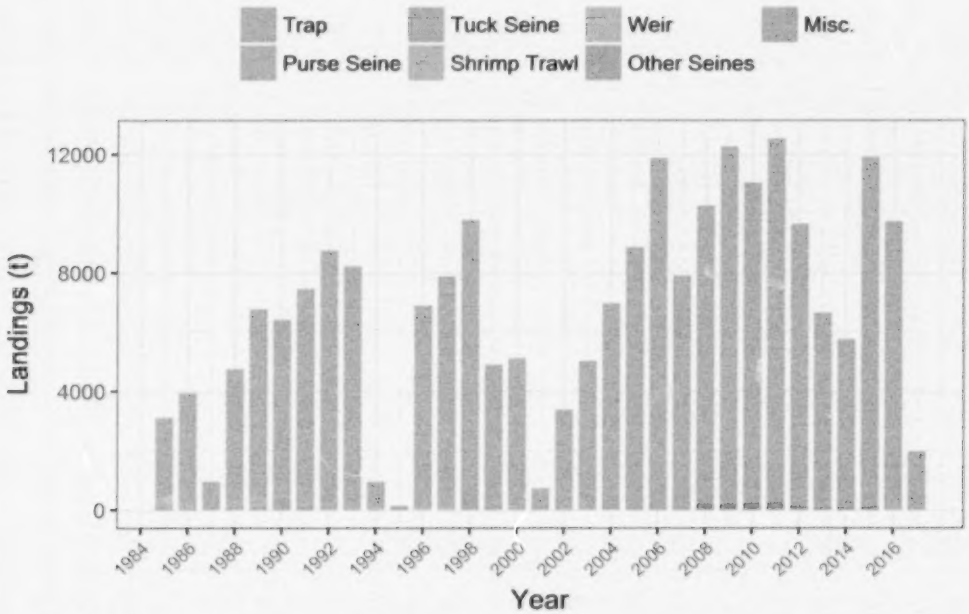

Figure 5. Capelin landings (t) by gear type in NAFO Divisions 4RST from 1985 to 2017.

The 2000-2017 fishing seasons

From 2000 until 2004, landings in 4R represented over 97% of the total landings. From 2005 to 2013, landings from 4S and 4T varied between 4-21% and 0-12% of the total landings, respectively. From 2013 on, landings in 4ST have dropped (Table 1).

The three main fishing gears used are purse seines, tuck seines, and traps (Figure 5, Table 1). Purse seines have consistently dominated the fishery, whereas tuck seiners have only emerged as an important gear type since 2005, and landings from traps have varied over time. In 2017, landings associated to these fishing gears were 1 964 t, 19 t, and 1 t respectively.

Table 1. Estuary and Gulf of St. Lawrence capelin landings (t) by NAFO Division and gear type from 2000 to 2017.

NAFO Division

NAFO Division	YEAR																	
	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
4R	5129	741	3295	5032	6975	8522	9322	6097	7846	10147	8769	9890	8914	6350	5683	11361	9289	1954
4S	0	0	77	0	0	305	2039	1344	2126	527	795	974	478	236	20	107	56	19
4T	0	0	20	0	0	34	518	471	99	1405	1258	1449	147	0	0	357	395	1
NA	0	0	0	0	0	0	0	0	206	196	234	238	115	69	71	98	0	0
Gear																		
Purse seine	5129	741	3295	4654	4639	5485	7335	5097	6916	7445	7197	7760	6568	4633	3667	7009	7037	1457
Tuck seine	0	0	0	0	0	182	788	530	967	1657	1558	1271	2204	1047	1477	3834	2080	496
Other seine	0	0	0	0	188	116	193	133	54	141	0	93	82	0	190	41	0	0
Trap	< 1	0	7	379	2148	3078	3562	2151	2135	2837	2067	3189	684	906	370	940	623	21
Weir	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Shrimp Trawler*	0	0	2	0	0	0	0	0	0	0	< 1	0	0	0	0	0	0	0
Miscellaneous	0	0	87	0	0	0	0	0	0	0	< 1	0	0	0	0	0	0	0
NA	0	0	0	0	0	0	0	0	206	196	234	238	115	69	71	98	0	0
Total	5129	741	3392	5032	6975	8861	11879	7911	10277	12276	11056	12552	9654	6656	5774	11923	9740	1973

* Shrimp trawler data recording not enforced

In 2017, most of the landings in 4R were made in unit area 4Rb (Figure 2) with a total of 1 198 t compared to 199 t (4Ra), and 557 t (4Rc). No landings were reported in unit area 4Rd. In 4ST, landings were only recorded in unit area 4Sw (Quebec's Lower North Shore) with 19 t and 4Tp (the upper St. Lawrence Esutary) with 1 t in 2017. Lower landings in traps and other fixed gear types along the shore (excluding tuck seines) in 2017 may be due to offshore deepwater spawning by capelin which would not be caught by those gear types. The question of whether this is just a change in all capelin behaviour, different populations of capelin being targeted by different gear types, or even a reflection of the behaviour of the fishery itself remains.

Location and timing of purse and tuck seine catches

Purse and tuck seine fishing activity on the West coast of Newfoundland can be heavily concentrated in certain areas some years. Fishing activity was relatively more evenly distributed across the NAFO unit areas prior to 2013 (though still very concentrated locally between Lourdes and Rocky Harbour in 4Rc and between Saint Pauls and Port au Choix in 4Rb). Since 2013 there are now proportionally more landings made in unit area 4Ra (Figure 6).

Landings are not only more concentrated in the Strait of Belle Isle (unit areas 4Ra and 4Sw) since 2013 but occur later and later in the season (Figure 6). Prior to 2013, most landings occurred in June. Since 2013, most landings occur in July in unit area 4Ra. Since 2007, most landings in unit area 4Ra have occurred in July. As of 2014, there have been landings in August, all of them around the Strait of Belle Isle. These observations are shared by the fishing communities and local residents of Newfoundland and Quebec.

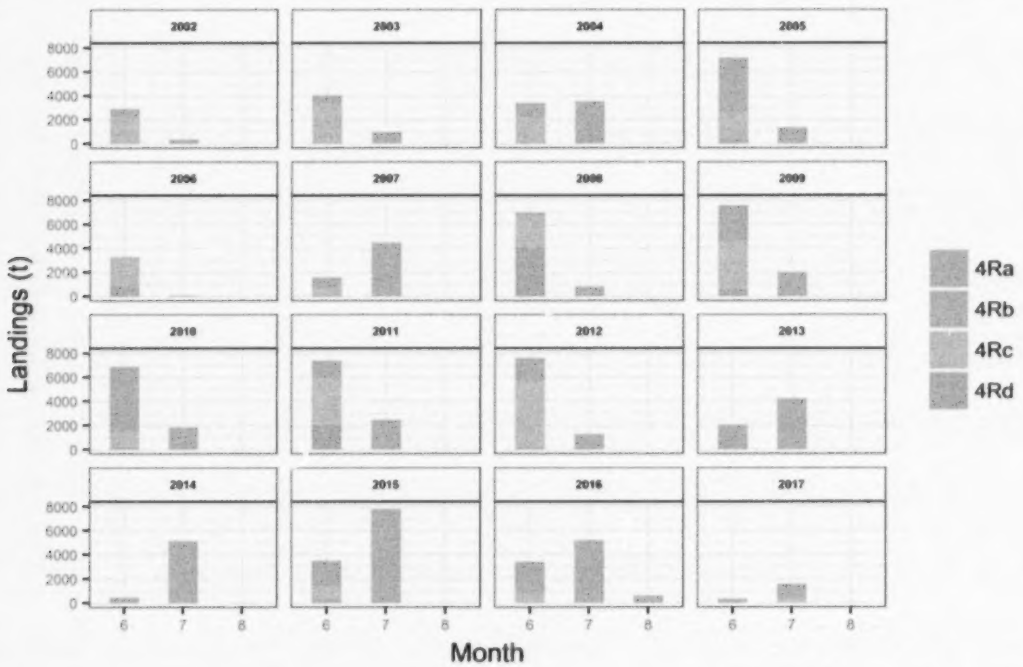

Figure 6. Capelin landings in NAFO Division 4R by unit area, year, and month of capture from 2002 to 2017.

Purse and tuck seine fishery performance

The performance of the 4R purse and tuck seine fisheries was calculated with a standardized index of catch per unit effort (CPUE; t/day/vessel). The seiner performance index increased from 2004 to 2013. Since 2013, however, the performance index has dropped by 35.3% to a value of 27.4 t/day/vessel in 2017 (a mean drop of 8.57% per year or roughly 3.63 t/day/vessel fewer fish). This value remains just above the upper limit of the time series mean of 20.78 ± 0.5 x 9.73 t/day/vessel from 1986 to 2017 (Figure 7). A similar performance index was also calculated for the 4Tn purse seine fishery in the Southern Gulf of St. Lawrence. However, the fit for the standardisation model is poor and no statistically significant trend can be discerned. This is most likely be due to the relatively small sample size of the 4Tn purse seine fishery.

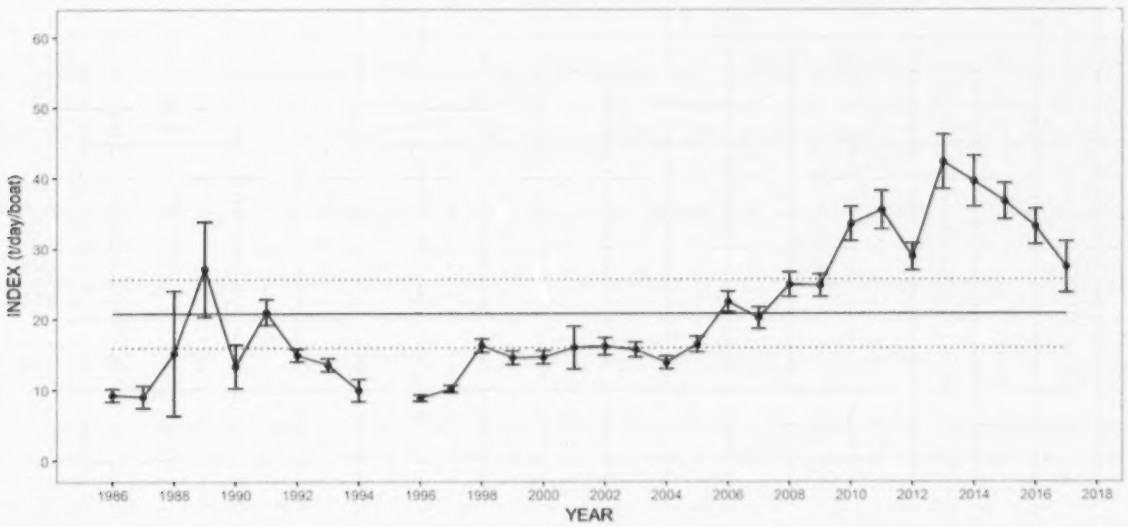

Figure 7. Purse and tuck seine fishery performance index (t/day/vessel ± s.d.) in NAFO Division 4R. The horizontal lines represents the mean performance index from 1986 to 2017 (solid line = 20.78) ± 0.5 x 9.73 (dotted lines).

Description of capelin caught in the commercial fishery

There are proportionally more males obtained from commercial fishery samples annually than females (mean of 62% males vs. 38% females). This could reflect a true sex ratio as there would have to be many more males in the population to compensate for the high mortality in post spawning males. It is also possible that more males are caught as they tend to stay in aggregations in coastal waters longer than females prior to spawning (Figure 8).

In the Estuary and Gulf of St. Lawrence, mean lengths for both female and male capelin samples provided by the commercial fishery have fluctuated over the years but show similar trends (Figure 9). From 1984 to 2017, females and males averaged 147 mm and 165 mm in 4R, 146 mm and 163 mm in 4S, and 140 mm and 148 mm in 4T respectively. In 4R, females decreased in size from 1992 to 2003, reaching a low point in 1999 at 135 mm. They increased in size in the 2000s to an all time high of 169 mm in 2014 and have decreased to the lowest average length on record in 2017 at 134 mm. Males in 4R followed similar trends, decreasing and increasing during the same time periods as females, reaching the highest mean length in 2014 at 181 mm and their lowest values in 1999 and 2017 at 152 mm and 154 mm respectively (Figure 9). As fishing effort is dependent on fish size and weather conditions, the fishery has closed early or been delayed many times throughout the years. In June of 2017, ice entered the Straight of Belle-Isle and delayed the beginning of the capelin fishery.

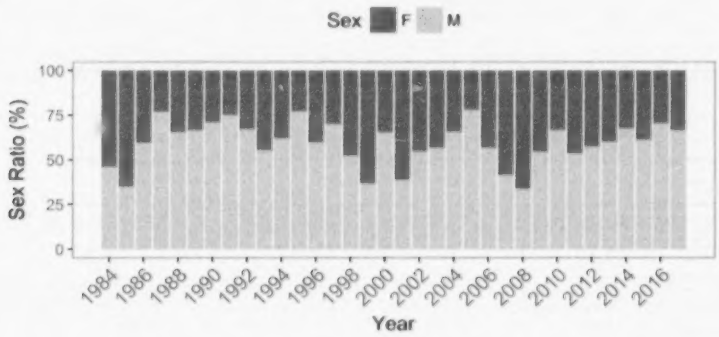

Figure 8. Proportion of male and female capelin samples obtained from the commercial fisheries in NAFO Divisions 4RST from 1984 to 2017.

When compared to the West coast of Newfoundland, 4ST mean annual lengths for both male and female capelin are smaller (Figure 9). Capelin in 3KL on the East coast of Newfoundland are generally larger than capelin in 4RST but dropped sharply in size (and in biomass) at the same time as the Atlantic cod stock collapse in the early 1990s. Their sizes have remained closer to Estuary and Gulf of St. Lawrence capelin populations ever since.

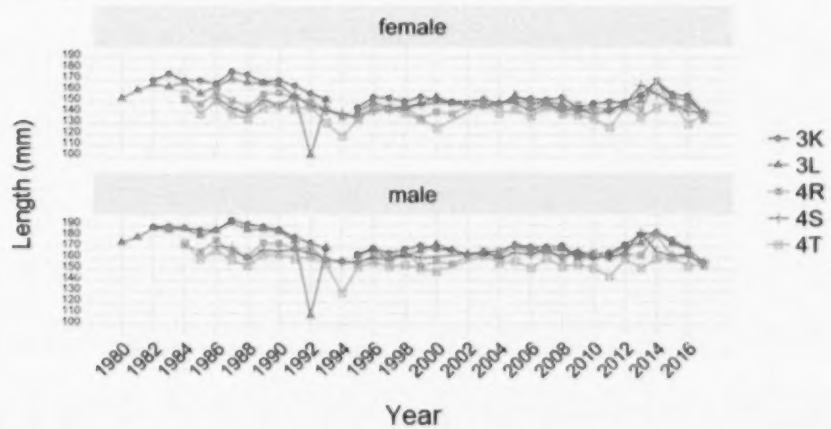

Figure 9. Mean lengths for male and female capelin in NAFO Divisions 4RST and 3KL.

Fluctuations in capelin size are also observed in annual length frequencies (Figure 10a,b) between sexes and across NAFO unit areas. Since 2014 both male and female sizes have decreased markedly (a decrease of 18% for females and 6% in males). This trend is most apparent in 4R as the majority of commercial samples come from that fishery. As capelin are a short lived species that attain their adult sizes within the first 2 years of life, length frequencies tend to only have one observable mode as they overlap with various age groups. There is less of a discernable trend in samples from 4ST which may just be due to smaller numbers of samples obtained from these fisheries.

Both male and female capelin have nearly linear weight-length relationships suggesting isometric growth patterns; however, the commercial fishery targets reproductive adults and it is rare to obtain capelin samples under 120 mm or under 10 g (Figure 11a). The early life stages of capelin in the Estuary and Gulf of St. Lawrence are therefore not fully understood. Capelin

condition has varied around a mean value of 0.6 from 1984 to 2017 for both males and females. Capelin condition was above average for both sexes in the 2000s reaching a peak in 2010. Since then, both male and female condition have dropped by 18% (Figure 11b).

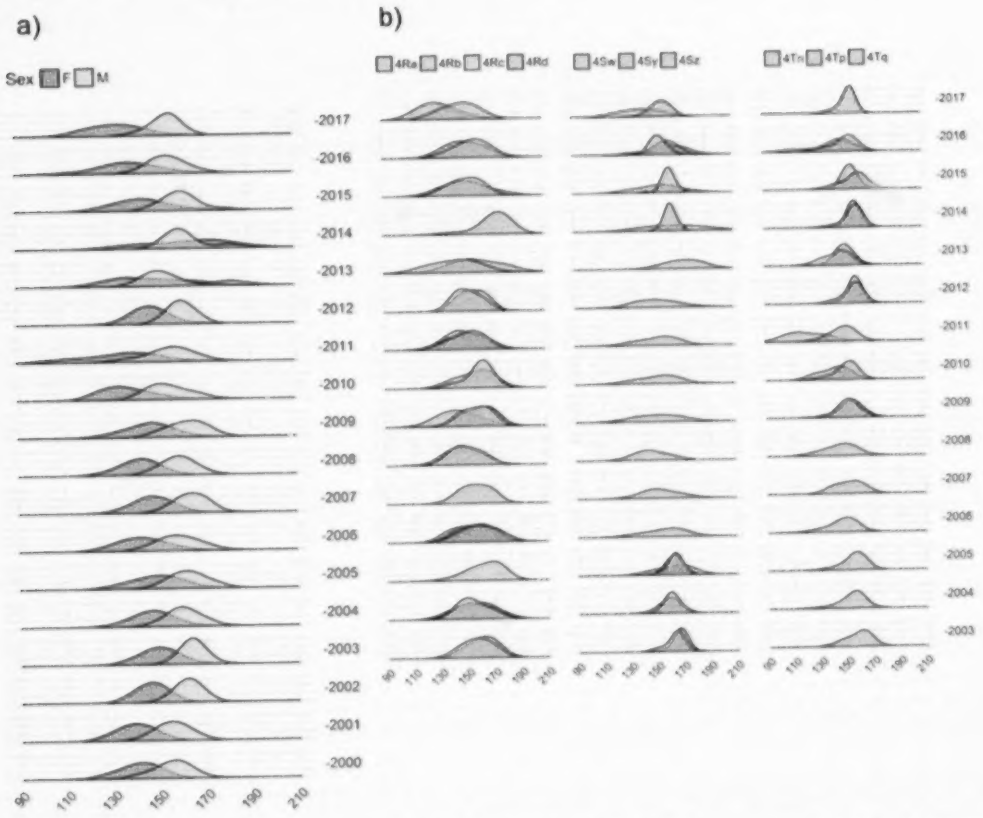

Figure 10. Density plots for length frequencies of capelin provided by the commercial fisheries grouped by a) sex and b) NAFO unit area.

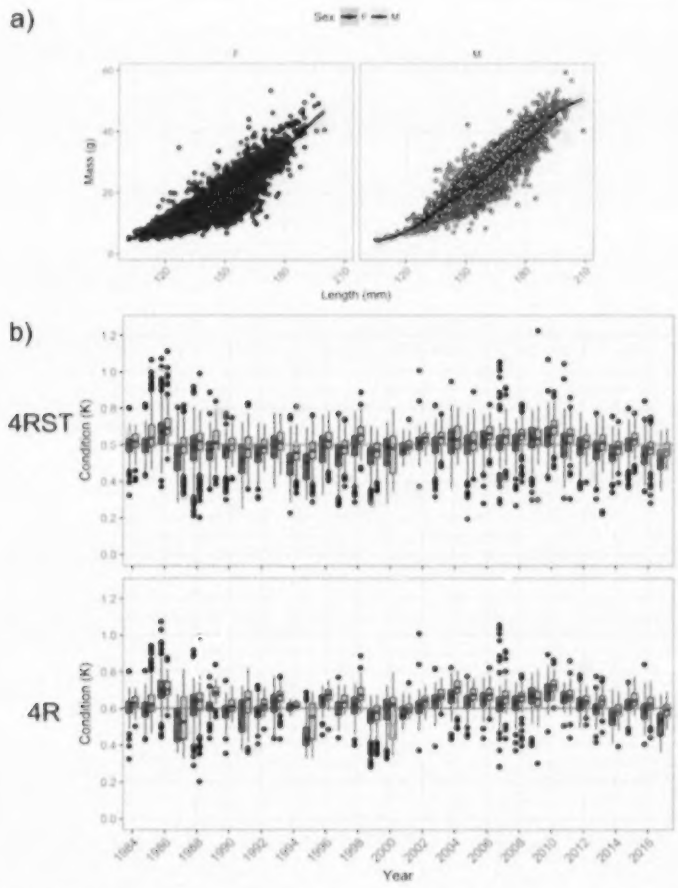

Figure 11. a) Weight-length relationship for female (blue) and males (orange) and b) box and whisker plots of capelin condition (Fulton's K) for the entire Estuary and Gulf of St. Lawrence and Division 4R alone. The redline represents the time-series mean for males and females.

Fishery Independent Data

Capelin caught in the Fisheries and Oceans Canada multidisciplinary shrimp and groundfish surveys

In previous 4RST capelin stock assessments the presence of capelin in the annual summer multidisciplinary shrimp and groundfish surveys in the Estuary and Gulf of St. Lawrence were presented as extrapolated occurrence maps and a dispersal index (Grégoire et al. 2012). As these surveys employ a bottom trawl to take samples and capelin are a pelagic species these results do not accurately reflect the presence of capelin as the catchability of capelin in the trawl is very likely to be influenced by environmental factors (McQuinn 2009). As a first step towards standardizing the survey data with factors other than by number of capelin caught, we tested a subset of the survey data (4T) as to wheher the presence of capelin in a trawl sample was significantly affected by 1) the presence of one of its main predators: the Atlantic cod, 2) water temperature, 3) mean trawl depth, and 4) time of day. The results indicate that each of the aforementioned environmental variables significantly influences the probability of catching capelin in the trawl survey. Capelin were roughly 25% more likely to be found in water

temperatures between -2.0 and 2.0 °C as well as between 4.0 and 8.0 °C but less likely to be caught at these temperatures when cod were present. Capelin were almost 75% more likely to be caught at depths of 75 m to 200 m and depths greater than 350 m but this dropped by nearly 25% when Atlantic cod were present. Finally capelin were roughly 25% more likely to caught at night but this dropped by half when Atlantic cod were present. They were also more likely to be caught during the day when Atlantic cod were present. Based on these results, the dispersal index that was formerly presented was determined to have a bias as these environmental factors vary from year to year.

These results are similar with recent analyses done on capelin off the East coast of Newfoundland that have shown that environmental conditions that determine the timing and magnitude of the spring bloom in the pelagic zone predict capelin recruitment. Taken together, this suggests that the 4R seiner performance index could reflect variation in capelin recruitment and stock size in the Gulf of St. Lawrence. More work is required on this topic before in can be used in the stock assessment but results are promissing.

Ecosystem considerations

Capelin have a central role in the Estuary and Gulf of St. Lawrence ecosystems as they allow the transfer of energy from primary and secondary producers to higher trophic levels. Capelin are an important prey for groundfish: Atlantic cod (*Gadus morhua)*, redfish (*Sebastes spp.)*, and Greenland turbot (*Reinhardtius hippoglossoides*), Cetaceans: Atlantic white-sided dolphins (*Lagenorhynchus acutus*), white-beaked dolphins (*Lagenorhynchus albirostris*), harbor porpoises (*Phocoena phocoena*), belugas (*Delphinapterus leucas*), Fin whales (*Delphinapterus leucas*), humpback whales (*Megaptera novaeangliae*), orcas (*Orcinus orca*), and minke whales (*Balaenoptera acutorostrata*), seabirds: gulls (*Larus spp.*), Atlantic puffins (*Fratercula arctica)*, and Northern gannets (*Morus bassanus)*, seals: particularly harp seals (*Pagophilus groenlandicus*), as well as many other fish species.

Marine ecosystem models indicate that between the mid-1980s and mid-2000s, capelin were the primary prey for the northern Gulf of St. Lawrence ecosystem and represented on average 50% of the consumed matter in the ecosystem. In the mid-1980s, the annual capelin consumption by its main predators was approximately one million tons. In the early 2000s, despite a sharp drop in cod and redfish abundances, nearly 400 000 t of capelin were still consumed by predators (Savenkoff et al. 2004*)*. More recent models as well as stomach content analyses of capelin's main predators indicate that they are not currently an important prey source for redfish or harp seals but remain an important staple for many other species in the ecosystem (Figure 12; C. Savenkoff, DFO Mont-Joli, pers. comm.). Fishing mortality does not appear to have a noticeable effect on capelin at current catch levels, although this is currently impossible to evaluate given the absence of a directed capelin acoustic survey.

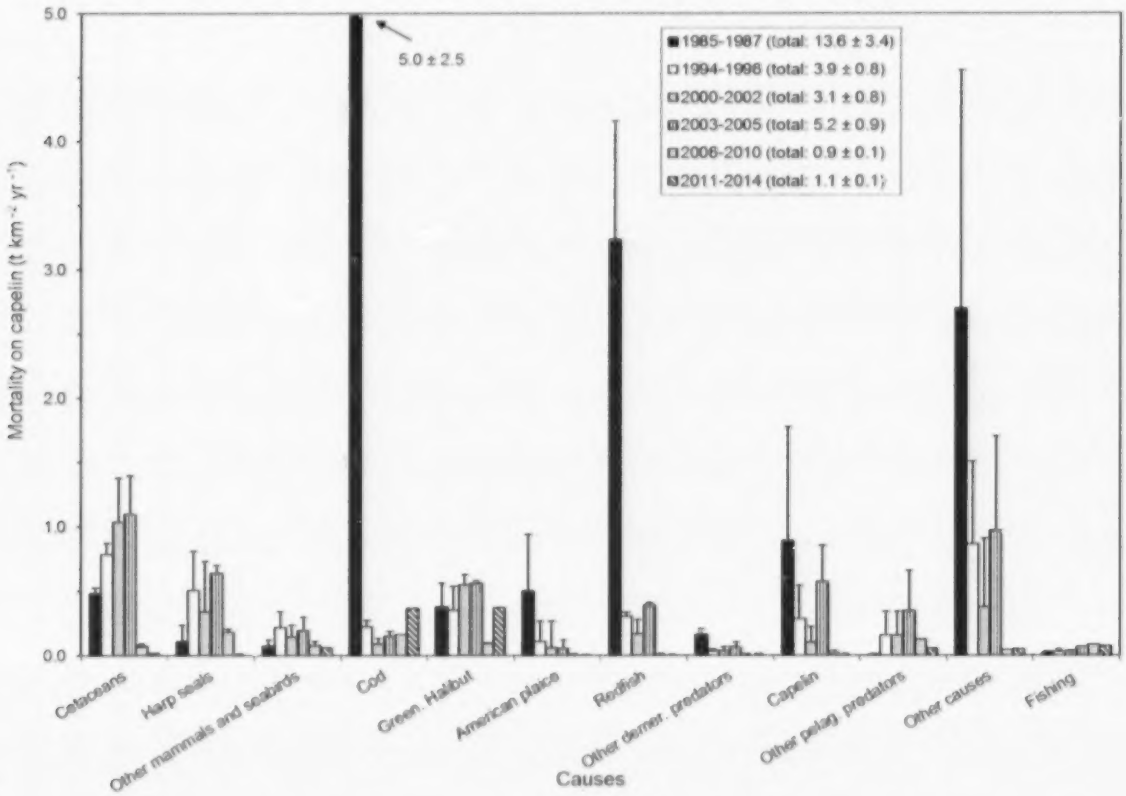

Figure 12. Detailed mortality by predation according to different northern Gulf of St. Lawrence marine ecosystem models (Divisions 4RS) from the mid-1980s to the mid-2010s. (Source: Claude Savenkoff - DFO)

Seiner performance is related to environmental conditions

Research on capelin populations on the East coast of Newfoundland has shown that capelin biomass is driven by bottom-up processes (Buren et al. 2014) and that 82% of the variation in age 0 capelin abundance can be explained by the match-mismatch between capelin spawning time and the spring bloom, as well as an abundance index for Calanus spp. Capelin larvae survival is therefore strongly linked to the availability of prey (Mullowney et al. 2016).

To explore the possibility of using the 4R seiner index as a relative recruitment index from two years ago or as a relative abundance index of the current year, we tested if seiner performance was associated with the same environmental processes that explain variation in capelin recruitment on the east coast of Newfoundland (Mollowney et al. 2016). To validate this analysis, we tested for temporal autocorrelation in the performance index to see whether our model should take an autocorrelation structure into account. A statistically significant temporal autocorrelation was detected in the detrended representation of the performance index with a 1 to 3 year lag, which corresponds with the life span of a capelin cohort in the commercial fishery. We then compared regressions that included all the environmental variables and various autocorrrelation error structures to conclude that the best fit to the model had a non-correlated error structure and a normal distribution.

Following these diagnostic analyses, we compared different formulations of the model through backwards selection to determine which environmental variables contributed to variation in the perfomance index 2 years later. The best model explained 72% of the variability in the performance index lagged by 2 years. The variables that contributed significantly to the performance of purse and tuck seiners in 4R were the following: The mean annual abundance of copepods (*Calanus hyperboreus and Calanus glacialis)*, the timing of spring warming, and the maximum volume of spring (mid-March) ice in the Gulf of St. Lawrence. Seiner performance increased when the timing of spring warming was later, when there was a greater volume of ice over winter, and when mean annual *C. hyperboreus* biomass was greater but decreased with greater mean annual *C. glacialis* biomasses two years earlier.

Sources of Uncertainty

The primary source of uncertainty is the absence of information regarding the size of the Estuary and Gulf of St. Lawrence capelin stock because we do not have an index of the stock abundance. There is also a lack of information on the number, the location, and size of spawning grounds and stock structure. Furthermore, there is very little information concerning the role of certain environmental variables on annual migration patterns.

The 4R seiner performance index does not represent an abundance index and should be interpreted with caution. Even if the performance index has a good fit when modeled with environmental variables that describe the timing and magnitude of the spring bloom from two years ago, as in the recruitment index on the East coast of Newfoundland, the performance index could be influenced by other factors. For example, fish behaviour, stock structure, technological advancements in the fishing fleet, and/or socio-economic factors.

Finally, we lack a fundamental understanding of how the different species and populations of capelin mix in the Estuary and Gulf of St. Lawrence and how their respective habitat preferences and behaviours might differ.

CONCLUSION AND ADVICE

Summary of the assessment

The main indicators of the fishery and stock status of the Estuary and Gulf of St. Lawrence capelin are the commercial landings, the mean lengths and condition of females and males, and the 4R seiner performance index. A model that takes environmental variables describing the timing and magnitude of the spring bloom into account indicates that seiner performance increased when the timing of spring warming was later, when there was a greater volume of ice over Winter, and when mean annual *C. hyperboreus* biomass was greater but decreased with greater mean annual *C. glacialis* biomasses two years earlier. Together the standardised yearly anomalies of these indicators show a marked downwards trend since 2014 (Figure 13).

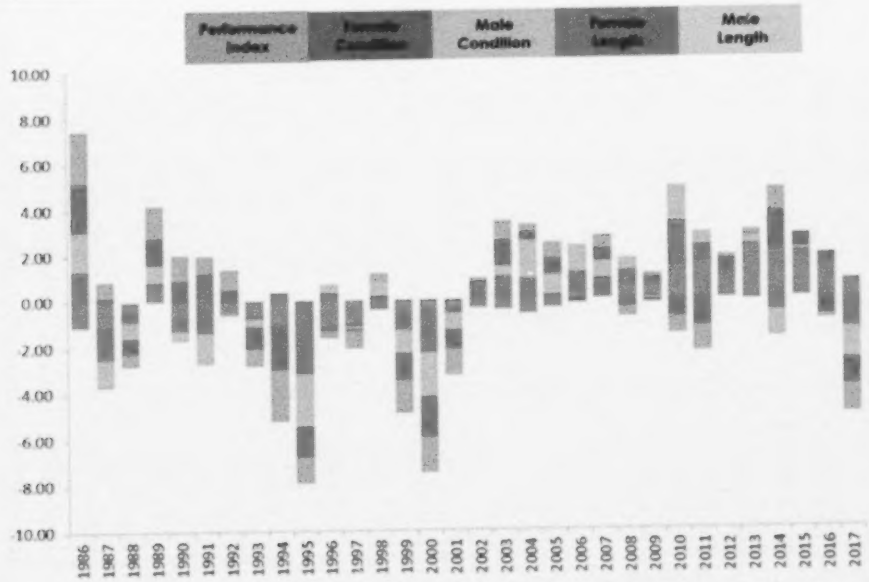

Figure 13. Sum of the anomalies of the main indicators of the fishery and stock status. The 4R seiner performance index (blue), female condition (red), male condition (green), female length (violet), and male length (light blue), from 1986-2017).

Recommendations

It is currently impossible to estimate the impact of landings on the capelin population(s) and the rest of the ecosystem because variations in capelin abundance are first and foremost the result of natural factors. As capelin have short lifespans, their abundances can be subject to large fluctuations as the populations consist of only a few age groups. To satisfy market demand, fishing effort is strongly correlated to the size of female capelin. The industry has a greater interest in regions where environmental conditions are more favourable to capelin growth.

Due to the decreasing fishery performance index, the decreasing biological indices, very low landings in 2017, and capelin's prominent role in the ecosystem as a forage species, a substantial decrease in the total allowable catch of capelin authorised for 2018 and 2019 is advised by virtue of precaution.

SOURCES OF INFORMATION

This Science Advisory Report is from the February 27, 2018 Assessment of Gulf of St. Lawrence capelin stock (4RST). Additional publications from this meeting will be posted on the Fisheries and Oceans Canada (DFO) Science Advisory Schedule as they become available.

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